Competency 1.5 **Radiation protection personnel shall demonstrate a working level knowledge of ALARA principles, and review and evaluate radiological programs, job planning, and job performance.**

1. Supporting Knowledge and /or Skills

a. Describe the various components of an effective ALARA program including operations, engineering, and management controls.

b. Explain the Department's role in the oversight of contractor ALARA programs.

c. Describe how cost-benefit analysis is used in the ALARA process.

d. Describe the various radiological performance indicators that are applicable to the ALARA process.

e. Discuss the essential elements of the job planning process and the post-job ALARA review for work performed in a radiation or radioactive contamination area.

2. Summary

The basic philosophy of As Low As Reasonably Achievable (ALARA) is to limit "personnel and environmental radiation exposures to the lowest levels commensurate with sound economic and social considerations."[1] The statement implies that no radiation exposure should occur without an associated net benefit considering technological, economic, and societal factors. Also implied is that any amount of exposure carries some risk which should be balanced by the benefit.

Some of the components of an ALARA Program are:

- Administration
- Optimization
- Setting and evaluating goals
- Radiological design
- Conduct of operations

Some of the key areas indicating an adequate administration of an ALARA program are listed below:

- Management commitment to ALARA. Usually, this commitment takes the form of a written policy statement.
- Communications, procedures, and manuals. The ALARA program must be adequately documented and communicated to workers.
- Training. Workers and supervisors must be trained in ALARA applications for specific job areas.
- Review and audit. Internal audits are valuable in identifying weaknesses or identifying areas for improvement.
- Staffing. The ALARA program must be adequately staffed for the duties and responsibilities involved.
- Organization. The ALARA program must be clearly and effectively organized.

The optimization process in ALARA refers to the process of achieving balance between radiation protection or reduction of risk, cost, and benefit. Radiation doses are ALARA only when these factors are in balance. If an imbalance exists, either the risk is too high, or the cost is too high for the identified benefit. The optimization process should be used whenever decisions regarding the implementation of a radiation protection practice will be costly, complex, and/or involve significant dose savings, for example, facility design and engineering controls. The major method of optimization is cost-benefit analysis, which is described in detail in ICRP publication 37, *Cost-Benefit Analysis in the Optimization of Radiation Protection*. The suggested approach to performing a cost benefit analysis includes these steps:[2]

- Identify all possible options, including the "do nothing" option.
- Determine the individual and collective dose equivalents for each option.
- Identify all costs and determine the net costs for each option.
- Determine the cost equivalent of the doses resulting from each option.
- Sum the costs to determine the total net cost for each option.

The option with the lowest total net cost is the optimal option.

ALARA goals should be set and evaluated periodically. The goals should be related to specific characteristics of operations and should correspond to real problems. Setting realistic goals is best achieved by a team including representatives from operations, engineering management and radiation protection. The goals may be quantitative and related to dose, such as average individual effective dose equivalent, quantitative but not related to dose, such as size of radiation or contamination area, or qualitative, such as establishing a computer program for tracking personnel doses.

The methods for achieving the goals can be classified into methods involving engineering and design, administrative methods, and radiation measurements.

The evaluation of goals can be accomplished by examining either dose related measures or non-dose related measures. One of the most common dose related measures is the average individual effective dose equivalent, which is the total effective dose equivalent for all exposed personnel divided by the number of persons exposed. Trend analysis of various parameters may be helpful in evaluating goals. For example, air sampling data or personnel exposures can be tracked over a period of time, perhaps after the implementation of a new ALARA goal.

The primary means for maintaining exposure ALARA should be through physical controls such as confinement, ventilation, remote handling, and shielding. Some of the factors that should be taken into consideration when designing new facilities or modifying existing ones are:

- Traffic patterns
- Radiation zoning
- Change room location and size
- Adequacy of personnel decontamination facilities
- Location of fixed survey equipment

Locations for the temporary storage of radioactive wastes must be designed into both the building plan and the plan for each laboratory room or radiation area.

The primary control of radiation exposures remains with the individual and with the individual's immediate supervisors. In many facilities, a major part of radiation exposure is received during maintenance, handling of radioactive wastes, in-service inspection, refueling, and repairs.[3] The two fundamental components of ALARA in the conduct of operations are the measurement of personnel doses (personnel monitoring) and measurement and characterization of radiation exposures in the field (radiation surveys).

Dosimeters should be appropriate for the kinds, energies, and intensities of radiation fields. The location where the dosimeter is worn on the body should be consistent and documented. The lens of the eye and the skin frequently require special consideration. Radiation surveys in the field provide a basis for making ALARA decisions in the field.

During operations, engineered controls are probably the most effective means of controlling exposure if included in the design and construction of a facility. Administrative controls are designed to provide guidance, direction and limitations for operational activities. Operational procedures are one type of administrative control. Each step in a procedure should be thought out, and its impact on exposure evaluated. For example, shielding, remote operation, distance, specialized tools, protective equipment, manpower requirements, exposure rates, exposure times and alternative procedures should all be carefully considered.

Planning of radiological work is essential. The purpose of planning is to ensure that all factors that may influence the adequate and efficient performance of a task are recognized and that appropriate skills, training, and resources are available. The Radiation Work Permit (RWP) is a radiation control procedure and essentially documents the planning process. The permit lists the radiation controls, requirements, and restrictions for work in a radiological area. Other important elements in the planning process are training personnel, scheduling work, briefing and debriefing workers, and documenting and analyzing historical data and work experiences. Upon completion of a task, a debriefing of those performing the work may be valuable in identifying problems encountered, techniques for improving the future performance of similar tasks, and techniques for further reducing exposures.

3. Self-Study Scenarios/Activities and Solutions

Scenario 1, Part A

Following a major repair of some contaminated equipment, the work area needs to be picked up. The work area is about 30 feet by 30 feet square. The initial plan calls for a worker to go into the contamination area to pick up debris. The debris consists of mainly absorbent paper, plastic, tools, and broken parts. The debris is to be sorted and disposed of in two radioactive waste containers located in the contaminated area. The ambient dose equivalent rate in the area is about 10 mrem/hr, with two marked areas of contamination where the dose equivalent rates are on the order of 50 mrem/hr (at 1 meter). The dose equivalent rates are attributable to gamma rays, and no airborne activity is present. In the corner of the work area is a small area which is roped off and properly labeled as a high radiation area. It is anticipated that it will take a worker in full protective clothing 30 minutes to do the job.

Briefly list important ALARA elements in the performance of this job that would begin to provide the basis for the RWP, and subsequent briefing of the worker. Estimate the dose equivalent to this worker for this job.

Your Solution:

Scenario 1, Solution
(Any reasonable paraphrase of the following is acceptable.)

The RWP will list the radiation controls, requirements, and restrictions for the work. The following are some elements relevant to this job:

- Since the area is a contamination area, protective clothing is necessary and must be worn. The clothing should probably consist of coveralls, gloves, shoe covers, and hood.
- The worker should wear at least a whole body dosimeter and pocket dosimeter.
- The worker should minimize the time near the most contaminated areas.
- The worker should be instructed not to go into the high radiation area to pick up debris.
- The worker should be instructed to pick up as much as possible in the 30 minute time frame, then exit the area.
- A supervisor should be outside the area to monitor the worker's time spent in the area, answer questions from the worker, and supervise the work.

A quick estimate of the dose equivalent to the worker would be:

$$(10 \text{ mrem/hr})\ (0.5 \text{ hr}) = \mathbf{5\ mrem}$$

Scenario 1, Part B

The worker was briefed on the objective of the job and the items on the RWP. The worker entered the area, and began to pick up debris. After a while he noticed that the radioactive waste containers were located right next to one of the spots with the highest contamination. He immediately dismissed this thought and decided to keep doing the task at hand. Upon being notified that the 30 minutes had elapsed, the worker removed the protective clothing, was frisked for contamination, and left the area. The worker's dosimeter read 10 mrem. A debriefing was held after the job was completed.

Briefly list some items that should be covered in the debriefing. Evaluate the worker's performance.

Your Solution:

Scenario 1, Part B Solution
(Any reasonable paraphrase of the following is acceptable.)

The debriefing should include the following items:

- Was the objective of the RWP met? Was the debris picked up and placed in the radioactive waste cans? Was the task completed, or was there more debris remaining that could not be picked up in the allowed time frame?
- Did the worker stay out of the high radiation area in the corner?
- Did the worker encounter any unanticipated problems that were not addressed in the RWP?
- Was the protective clothing appropriate for the situation (i.e., did it fail; would another type of clothing, or glove, etc., have worked better for the job to be performed)? Was it safe for the employee considering factors such as heat, humidity, lighting, water, etc.? Did it prevent contamination of the employee?
- Did the worker avoid the areas with the highest contamination?
- Were the pocket ionization chamber results within the limit set for the job? If not, what factor(s) contributed to additional exposure?
- What can be improved when other similar jobs have to be performed?

It appears that the job was performed according to plan with these exceptions: The worker had to spend more time than necessary near the areas of highest contamination since the radioactive waste containers were located there, and the worker's estimated dose equivalent for the job was greater than anticipated, perhaps for the same reason. As far as the worker's performance, he did notice the proximity of the waste containers to the contaminated spots, but did not question this. He could have moved the containers to a different location in the area, or asked the supervisor who was outside the area, about what to do in this situation. This may have contributed to the higher than estimated dose equivalent that the worker received. For future jobs, the workers could be instructed to move the containers to an area away from areas of highest contamination.

Scenario 2

Some vacuuming of radioactive dust needs to be performed around the vicinity of an accelerator. The magnet coils of the accelerator were recently repaired and some grinding of welds were necessary, resulting in radioactive dust to be cleaned up. The area where the vacuuming is needed is correctly posted as an airborne radioactivity area, a high radiation area, and a contamination area. Several options exist regarding the radiological aspects of performing the vacuuming work. The health physics supervisor is examining several options before writing up the RWP.

Specific information about the work area is listed below:

- Primary contaminant is manganese-54 (Mn-54) oxide.
- Ambient dose equivalent rate is 10 rem/hr.
- Job will take approximately 1.5 hours to perform.
- Measured airborne concentration is 5 times the DAC.
- A movable shield with arm ports could be used between the worker and the bulk of the dust to be picked up. This shield attenuates the dose equivalent rate to 1 rem/hr, but will increase the estimated job duration time to 2 hours.
- Respiratory protection with a protection factor (PF) of 50 is available, but will increase the estimated job duration time to 3 hours.

The health physics supervisor is examining the following options. All options assume that protective clothing will be worn during the job.

1. Use one worker, but no shield, and no respiratory protection.
2. Use one worker, use the shield, but no respiratory protection.
3. Use one worker, use the shield, and respiratory protection.

Activity 1

Estimate the total dose equivalent to the worker under for each option, and identify the option with lowest total dose equivalent.

Your Solution:

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Scenario 2, Solution

Option 1: no shield, no respiratory protection

External exposure:	(10 rem/hr) (1.5 hr)	=	**15 rem**
Internal exposure:	(5 DAC) (1.5 hr)	=	**7.5 DAC-hours**
	(7.5/2000 DAC-hrs) (5 rem)	=	**0.01875 rem** or **about 19 mrem**
Total dose equivalent:	15 rem + 19 mrem	=	**15.019 rem**

Option 2: use shield, but no respiratory protection

External exposure:	(1 rem/hr) (2 hr)	=	**2 rem**
Internal exposure:	(5 DAC) (2 hr)	=	**10 DAC-hours**
	(10/2000 DAC-hrs) (5 rem)	=	**0.025 rem** or **25 mrem**
Total dose equivalent:	2 rem + 25 mrem	=	**2.025 rem**

Option 3: use shield, use respiratory protection

External exposure:	(1 rem/hr) (3 hr)	=	**3 rem**
Internal exposure:	(5 DAC/50 PF) (3 hrs)	=	**3 DAC-hours**
	(0.3/2000) (5 rem)	=	**0.75 mrem**
Total dose equivalent:	3 rem + 0.75 mrem	=	**3.00075 rem** or **3 rem**

Clearly, option 2 results in the lowest total dose equivalent. All other factors being equal, this would be the best option.

Activity 2

What are some other options that the health physics supervisor might consider?

Your Solution:

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Activity 2, Solution

The health physics supervisor might consider using several people in short shift to perform the task. The advantage here is that the dose would be distributed among several individuals. This option would be especially attractive in meeting site specific administrative controls.

Activity 3

Identify a sensitive issue that the health physics supervisor can expect to arise when instructing the workers about the performance of this particular task.

Your Solution:

Activity 3, Solution

A sensitive issue that will arise on the part of the workers is why respiratory protection is not needed in an airborne activity area. The health physics supervisor must be very careful to explain the primarily external hazard associated with this particular radionuclide, even though dust containing the radionuclide is present. Also, the health physics supervisor must be sure to explain that the total risk to the individual is the result of BOTH internal and external exposure. This will be easier for the workers to accept if they have been properly trained to begin with, and if they are not hearing this concept for the very first time.

Footnotes:

1. Pacific Northwest Laboratory. (1988). *Department of Energy Health Physics Manual of Good Practices for Reducing Radiation Exposure to Levels that are As Low As Reasonably Achievable (ALARA)* (PNL-6577). Richland, WA: Author, p.1.2.
2. Ibid., p. 3.9.
3. Ibid., p. 6.3.

4. Suggested Additional Readings and/or Courses

Readings

- 10 CFR 835, *Occupational Radiation Protection*
- DOE N 441.1, *Radiological Protection for DOE Activities*
- DOE/EH-0256T (Revision 1), *Radiological Control Manual*
  NOTE: See Appendix 3A, Checklist for Reducing Occupational Radiation Exposure, pp. 3-35 & 3-36
- DOE Order 5480.4, *Environmental Protection, Safety, and Health Protection Standards*
- G-10 CFR 835, Revision 1, *Implementation Guides for Use with Title 10 Code of Federal Regulations 835*
- International Commission on Radiological Protection. *Cost -Benefit Analysis in the Optimization of Radiation Protection (ICRP 37).* New York: Author.
- International Commission on Radiological Protection. *Recommendations on the International Commission of Radiological Protection (ICRP 60).* New York: Author

- Pacific Northwest Laboratory. (1988). *Department of Energy Health Physics Manual of Good Practices for Reducing Radiation Exposure to Levels that are As Low As Reasonably Achievable (ALARA)* (PNL-6577). Richland, WA: Author.

Courses

NOTE: See Appendix B for additional course information

- DOE/EH-0450 (Revision 0), *Radiological Assessors Training (for Auditors and Inspectors) - Fundamental Radiological Control*, sponsored by the Office of Defense Programs, DOE
- *Applied Health Physics* -- Oak Ridge Institute for Science and Education
- *Health Physics for the Industrial Hygienist* -- Oak Ridge Institute for Science and Education
- *Safe Use of Radionuclides* -- Oak Ridge Institute for Science and Education
- *Radiation Protection Functional Area Qualification Standard* -- GTS Duratek

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